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COGNITIVE SKILLS: A CONSIDERATION IN EVALUATING INSTRUCTIONAL EFFECTS.
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Research related to the training and measurement of cognitive skills (effective behaviors in situations in which events must be organized or structured in some way) represents a point of common ground between the educator and the behavioral scientist. That we so seldom train for generalized cognitive skills is paradoxical, for most authorities tend to assume these skills enable the student to learn a wide variety of instructional content. Research on whether or not generalized skills interact with instructional content to facilitate learning is now under way. Knowledge of how cognitive skills develop is limited, but some findings suggest that research should concentrate on the more advanced stages of formal operations. It may be possible to develop more efficient and precise measures than those of Piaget. If so, they may be useful in evaluating educational programs because (1) measures of fundamental cognitive skills provide highly meaningful descriptive information about learners, (2) knowing the level of cognitive development attained by learners should provide significant information as to interactions between instructional phenomena and learning, and (3) we may find that the development of some cognitive skills is actually facilitated by a given instructional program. (JS)

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W. Skager writes about cognitive skills and instructional effects.

cognitive skills: a consideration in evaluating instructional effects

The term "cognition" refers in a general sense to the process by which individuals apprehend or become aware of what is going on around them. However, the theory and research usually classified under the label "cognitive" have a somewhat more restricted referent. In particular, "cognitive skills" refers to how effectively an individual behaves in situations in which events must be organized or structured in some way. The implication is that there is some sort of generalized process available that can be applied to a wide variety of specific situations.

The search for fundamental, organizing principles in cognition has exciting potential for education. Moreover, it represents a point at which there is an unusual amount of common ground between the educator and the behavioral scientist.

In the work of Piaget, subjects are often asked to make predictions about the characteristics of physical objects or to explain events involving the behavior of natural objects in various situations. The purpose of this line of questioning is to determine what kind of general thinking skills are available to the child, not to find what he knows about the properties of natural objects or the mechanical aspects of physics, per se. In the case of the familiar conservation problem, the subject must make predictions about some attribute of an object in the face of irrelevant and potentially misleading perceptual cues. For example, in the conservation of displacement volume the child is first shown two identical clay balls and two identical glass beakers; each of the beakers contains exactly the same amount of water. He is then asked to drop one of the clay balls in each beaker and to observe what happens to the respective water levels. It is quite easy for even the relatively young child — say of five years — to note quickly that, while the water level has risen in both breakers, the respective levels have remained equal. The irrelevant perceptual cue is established when the experimenter removes the clay balls, flattens out one of them, and asks the child to make a prediction as to the water levels were the two pieces of clay — one still shaped like a ball, the other a pancake — to be returned to the beakers. Once the prediction is made, the child is (or should be) asked to explain the basis on which it was made. If he indicates that the water in the beaker containing the flat piece of clay will not rise as high because the clay is "thinner," or offers another incorrect explanation of a similar type, we conclude that the child is unable to "hold on to" (or conserve) the idea that the clay takes up the same amount of space regardless of the transformation in shape. In Piaget's view, the correct explanation indicates that the child is able to utilize a generalized principle of compensation. That is, he recognizes that while one dimension (height) has decreased, another dimension (width) has increased. In a strict sense, then, it is the explanation, rather than the correctness or incorrectness of the prediction, that provides us with evidence as to the nature of the organizing or structuring principles underlying the cognitive processes.

At the "concrete operations" stage of cognitive development — from approximately seven to eleven years — the child's judgmental processes become increasingly independent of irrelevancies which are directly related to perceptual cues. The child achieves this independence from perceptual cues by forming differentiated quantitative concepts, such as conservation of matter, which are illustrated by performance on conservation tasks (the best known of the Piagetian procedures).

There is also a growing ability at the stage of concrete operations to utilize two types of logic: operations of class inclusion (e.g., in arithmetic, when part-whole relationships are manipulated by addition) and operations of seriation (e.g., the ability to arrange objects in a series according to some attribute and to find similarities between series).

Cognitive functioning at the stage of concrete operations significantly is characterized by one limitation: operations utilized in problem solving are mainly confined to dealing with the actual or phenomenal rather than with the possible or hypothetical. The formal reasoning adolescent is able to take a hypothetical approach to problem solving. This ability to rise above the phenomenal is the essential difference between the stages of concrete and formal operations.

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At the higher level of formal operations, the nature of the explanation is still the primary basis on which Piaget would make inferences as to level of cognitive development. In the "floating bodies" problem, for example, children are provided with an array of objects — a wooden block, a metal box, a rubber ball, and so on — some of which float and some do not. Insofar as possible, for each object that does float there should be a counterpart of the same material that sinks. Along with the rubber ball of low density, there might be, say, an eraser of relatively high density. The child is first asked to make a prediction about whether or not each object will float and to state why he has made each prediction. He is then provided with a tub of water and allowed to test each of his predictions empirically, at the same time explaining why the particular object was observed to float or sink. If he fails to arrive at an explanation consistent with the law of specific gravity by the time this process is completed, he is asked whether or not he can think of any rule that covers all cases.

The critical cognitive problem posed by this task involves the need to consider two characteristics of the object, weight and volume, at the same time. Only by so doing can the child determine how heavy the object is in comparison with an equivalent volume of water. Any explanation which focuses on a single attribute of the object is bound to be inadequate. The fact that correct predictions can be made is trivial. Thus, an entirely correct set of predictions obviously can be achieved if the child has had enough relevant experience with the particular set of objects, but this experience will not generalize to a new set of objects unless the child has formulated in an implicit way a general organizing principle, i.e., the law of specific gravity.

"research project involving children of normal scholastic aptitude, but . . . at least one year behind in mathematics achievement"

In recently using the "floating bodies" problem in a research project involving children of normal scholastic aptitude, but who were at least one year behind in mathematics achievement, we were astonished to find, at the most primitive level, a 13-year-old girl whose explanations were clearly of an animistic type. (Things float "because they are dead and sink because they are alive.") I might say, parenthetically, that this was the only truly general rule that any of the 100 subjects managed to generate.

At another level of organization, we observed that many, perhaps a majority, of the 12- and 13-year-old children were unable to adjust even very specific rules to contradictory experience. For example, they would still cling to the idea that metal things sink, in spite of the fact that one of the metal objects was observed to float. Although none of the children managed to state the law of specific gravity — in other words, to make the jump from an explanation based on only a single attribute of the object — a few children did reject their earlier explanations on the basis of contradictory experience. Such children would conclude that they did not really know the rule after all, but that it did have something to do with how heavy the object was.

I have described the above measures of cognitive development in detail, because it seems important to establish that cognition is an active process of organizing experience, as contrasted with the mere recognition of an order that already has been established. We recognize specific words on a vocabularly list of a scholastic aptitude test, but the recognition has become automatic and requires little from the subject in the way of cognitive skills as defined here — generalized abilities to apprehend and explain a set of observations that are in some sense novel.

We rarely view cognitive skills, at least of the type I have been describing, as among the deliberate objectives of instruction. To be sure, the term or one of its variations frequently appears in descriptive materials, such as test manuals and curriculum goals, but it may be difficult to discover specific examples in the actual test items or learning procedures. By the time students learn about the law of specific gravity, the majority have reached the point where they can generate the law themselves, at least in verbal form, if given the opportunity. It is true that we

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teach concepts. However, we usually do so with respect to specific educational content rather than as a generalized skill transcending particular content. To use a somewhat different example, we do not, as far as I know, set about training children to group things according to what Bruner (1964) calls superordinate concepts, that is, grouping in terms of a single general principle or attribute rather than by far less satisfactory and more complex strategies (telling a story about the objects or generating a different concept for each pair of objects in the set).

That we so seldom train for generalized cognitive skills is in a sense paradoxical, because most authorities tend to assume that these skills enable the student to learn a wide variety of instructional content. Most of us probably would accept the notion that the child develops cognitive models as a result of his informal, non-school experiences, which later on help considerably in formal educational situations, such as learning about the nature of numbers and numerical operations. Thus, in some way the average child manages to learn by himself how to place objects in a series according to their magnitude on a scale and how to make correspondences between objects in the same position in different series. Children at six or seven, or even earlier, can quickly order a set of toy trucks according to size and alongside that series order a set of loads so that the appropriate load is adjacent to each truck. This ability to construct serial orders should give the child a model for understanding the ordinal property of numbers. The ability to make one-to-one correspondences between objects in different series should help him to understand that a number is one way of defining a unique, yet highly inclusive class. When the child has learned to count, he also will learn—again usually entirely on his own—that such correspondences can be established without the tedious, concrete-bound process of matching one by one the objects in the two series.

"at . . . CSEIP, some of us are looking into the question of whether or not measures of generalized skills . . . do accompany a greater ability to profit by mathematics instruction"

At the Center for the Study of Evaluation of Instructional Programs (CSEIP), some of us are looking into the question of whether or not measures of generalized skills, including those just mentioned, actually do accompany a greater ability to profit by mathematics instruction. It seems to me that such efforts to relate cognitive skills to the ability to learn material, which according to our theories presupposes the development of such skills, are highly important.

A familiarity with some aspects of Piaget's theory, for example, tends to establish the conviction that quantity conceptions represent important milestones in cognitive development. Yet, the conviction is primarily rational, unverified by any empirical test. It would therefore be appropriate for us to indulge in what is usually referred to as construct validation—to see, for example, if children who demonstrate seriation, ordination, and cardination in a testing situation are in fact able to learn things that other children without such cognitive skills are either unable to learn or are able to learn only very slowly. Indeed, if the cognitive skills discussed here are not found to be related to other aspects of performance—learning, problem solving, and so forth—I for one would begin to feel that we have been wasting our time, not only as educators, but also as behavioral scientists. Let me hasten to add that I do not expect this to be the case.

Whether or not such fundamental cognitive skills interact with instructional content in such a way as to facilitate learning is thus a highly salient issue in research relating to education. At this stage we can at least make suppositions about certain interactions. However, when it comes to knowledge about how cognitive skills develop, we are not nearly so well off. This is one reason why we are not doing very much about training generalized skills in the classroom.

I do not think that anyone would maintain that cognitive skills as defined here are preprogrammed into the developing organism, to unfold spontaneously regardless of the nature of prior interaction with the environment. Even Piaget and his co-workers, who are quite disdainful of the now common attempts by laboratory researchers to accelerate the attainment of various types of conservation, do see all of the concrete operations as originating in some type of interaction with the environment. After the early stages of infancy, however, the nature of such interaction is not clear.

Thus far, only a few shreds of evidence—such as Goodnow (1966) has reported—suggest that the development of cognitive skills is related to such a presumably potent variable as whether or not a child has had formal schooling. In her research, Goodnow compared groups of children who differed in amount of education, as well as in various other ways. Three conservation tasks were administered, along with a formal reasoning task which required the child to generate all possible pairs of a set of colored chips. The latter, or combinations task, is complicated enough to require the application of a systematic strategy in order to succeed. In a manner analogous to the floating bodies task, the scoring depends on the nature and inclusiveness of the strategy employed rather than simply on the number of pairs of colors laid out. One of the groups of children in Goodnow's study had had no schooling at all, and it was therefore something of a surprise to learn that this group did as well on the conservation tasks as did other groups of similar chronological age and mental age, but who had had the benefit of varying amounts of schooling.

In contrast, the unschooled children performed far more poorly on the combinations task. Goodnow suggested that the normal requirements of this task – that "things be worked out in the head"—gave the child who had been to school an advantage, while the experiences contributing to the learning of the lower level conservation concepts may be so common within any human cultural environment that little can be expected in the way of educational effects. These findings also suggest that it is at the more advanced stage of formal operations, so far almost completely neglected in research on the training of cognitive skills, that we should be directing our efforts.

Paralleling the evident contemporary interest in the manner in which cognitive skills develop and interact with instructional variables, there is a concern with how these skills ought to be measured. The methods developed by

Piaget are time-consuming, highly individualized procedures whose precise replicability is in question. Indeed, whenever results differ widely from those reported from Geneva, we inevitably wonder whether or not things were done in the same way. Thus, we have confusing findings. Elkind (1962) reported that only barely more than one-half of a sample of American college students had attained conservation of volume, in spite of the fact that the normal child, according to Piaget, should have attained this last conservation concept by the age of 12 or 13. In our own preliminary work, we have noted repeatedly that the child's initial understanding of the nature of the task, as well as the questions asked by the experimenter, are critical variables affecting his performance.

It may be that more efficient and precise measures can be developed by measurement experts, and studies have been done along these lines involving pictures instead of actual stimulus objects. Some objective test formats have even been tried out. I doubt, however, that any of these new methods, even if successful, will provide the average child with as much obvious enjoyment as does the chance to drop a few pieces of junk into a tub of water.

"the need to refine and standardize measures of cognitive skills is related to . . . the evaluation of educational programs"

The need to refine and standardize measures of cognitive skills is related to a more pragmatic and immediate concern—the evaluation of educational programs. The work on cognitive development, which I have previously mentioned, that is going on at the Center for the Study of Evaluation of Instructional Programs in part involves an attempt to evaluate the learning outcomes achieved by teachers utilizing materials developed in a modern mathematics curriculum project. As a part of the evaluation battery, we have administered a number of measures of cognitive skills developed by Piaget, as well as one measure of grouping strategy designed at the Center. We feel that measurement of cognitive skills, used, of course, in conjunction with more direct measures of mathematical achievement, can make the conclusions in the evaluation far more meaningful than would otherwise be the case.

Why is this so?

First, *measures of fundamental cognitive skills provide highly meaningful descriptive information about the sample of learners ~~participating~~ in the evaluation.* Knowing, for example, that a given percentage of the learners are unable to perform the cardination operation seems to me far more informative as to the origin of learning difficulties than is the observation that the group mean on a standardized mathematics achievement test is low when referred to national norms. Other than in this gross, normative sense, scores on standardized achievement tests are very difficult to interpret, unless one is willing to study response patterns at the level of the individual item. Performance on measures of cognitive skills, in contrast, usually can be referred to as theory and research on human development.

Second, *knowing the level of cognitive development attained by the learners should provide significant information as to interactions between instructional phenomena and learning.* By this I mean that the evaluator can provide very useful information to curriculum developers and others when he observes that certain methods or materials work better for certain types of students. At present, we give considerable emphasis to social and cultural factors when considering the potential effectiveness of instructional programs. Knowing what sorts of cognitive skills are available to the intended learners ought to be equally important. It is no secret that in recent years great efforts have been made to develop modern curricula that are appropriate for the highly able learner. Yet, many cases exist where these same curricula were applied, willy-nilly, to groups at a far less advanced level of development. In studying the potential of such new curricula, then, the evaluator should be highly concerned with measuring the cognitive characteristics of the learners.

Third, *we may find that the development of some cognitive skills is actually facilitated by a given instructional program.* This hope may be unduly optimistic in view of the confused results emanating from laboratory research attempts to accelerate the development of cognitive skills. However, formal instruction actually represents a more massive and extended intervention into the learner's life than is ever granted to behavioral scientists working in the laboratory. Some of the modern curricula, particularly in mathematics, appear to stress the learning of operations that look suspiciously like the operations of one-to-one matching, seriation, and cardination mentioned earlier in this article. If students under a given instructional program were found to have accelerated in some aspects of their cognitive development, it would certainly be of the greatest significance to those considering the adoption of that program. Such a finding should be of equal interest to people engaged in what is usually referred to as "basic" research on cognitive development.

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